A Conceptual Modeling Approach to Quality Management in The Context of Diary Supply Chain

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Abstract—**The Chinese milk scandal 2008 revealed a serious problem in supply chain quality management practices.In this research, conceptual modeling approach is used to represent entities and relationships in this field. The model is expected to provide an innovative perspective to supply chain quality management. With it, intelligent system can be designed to support quality information sharing between agents in the whole milk supply chain, and real time quality problem (e.g. causation of heavy metal residual) detection is feasible.**

Keywords-milk; supply chain quality management; static ontology; social ontology; conceptual modeling

I. INTRODUCTION

In recent years, increasing consumer concerns and the consequential costs imposed on society and food industry as a result of food safety incidents have led to an increased focus on the quality food. The Chinese milk scandal, which broke on July 16, 2008, revealed a serious quality management problem in inter-organizational collaboration. Thus, quality issues of supply chain should be paid more attention. Supply chain quality management is defined as a systems-based approach to performance improvement that leverages opportunities created by upstream and downstream linkages with suppliers and customers [1]. In this paper, supply chain quality management in the context of milk industry will be studied, and this study includes more organizations such as food quality supervision and inspection department. .

In the milk supply chain, downstream organizations, government have dynamic requirements specified in quantitative and qualitative criteria about quality of stock from upstream organizations. Quantitative criteria can be achieved by using corresponding quality inspection tools such as Liquid Chromatography-Electrospray Lonization Tandem Mass Spectrometry for determination of antibiotic residues in raw milk [2]. However the qualitative criteria is subjective, for instance, “raw milk must not be adulterate”. It is very difficult for downstream organizations or government organizations to share the qualitative quality information due to the upstream organizations’ individual preferences and dynamic evolution, which result in quality information loss among organizations. Thus, until now, diary product safety can not be assured based on both quantitative and qualitative information timely in a global dimension, which may cause diary incidents like the milk scandal above [3] and increased quality management cost. In this paper, entities of quality management practice in the milk supply chain together with relationships among them will be represented in the conceptual model. Entities have classes of organizations, quality criteria, inspection tools, etc. The model is expected to propose an innovative perspective to quality management in a global dimension(i.e. the whole supply chain quality management) . With it, intelligent system can be designed to support quality information sharing between agents in the whole milk supply chain, and real time quality problem (e.g. causation of heavy metal residual) detection is feasible.

The organization of this research is as follows. In Section II, we present a literature review. Section III illustrates the conceptual model, followed by a case analysis. Finally, the paper is concluded in Section IV.Ease of Use

II. LITERATURE REVIEW

As emphasis on supply chain management is increasing, researchers have begun to rethink models, constructs, and frameworks for quality management. Kaynak and Hartley[4] examined influence of eight quality management practices including supply quality management and customer focus variables on quality related performance. Their study confirms that implementing quality management as an integrated system instead of just a loose set of quality practices is needed and suggests managers should extend their vision beyond their own firms into the supply chain to manage quality. Other researchers also did the similar work. But they did not mention how to conduct or support supply chain quality management by using information technology in a global dimension. Iraj [5] designed a framework of e-based quality management for distributed manufacturing system by combining statistical quality analyses and reporting capabilities with web technology to deliver process

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optimization solution. This framework is aimed to bridge the gap between raw data and genuine quality improvement efforts. However, no existing modeling and framework considered qualitative quality information in the food supply. So in this research, a conceptual modeling approach will analyze the milk supply chain quality management by adding the factor of qualitative quality requirement.

III. THE CONCEPTUAL MODELING APPRACH TO QUALITY MANAGEMENT IN THE DIARY SUPPLY CHAIN

In this section, both the static and social ontology design for quality management practices in the milk supply chain is described based on the research by Jurisica, Mylopoulos and Yu [7]. OWL and the SWRL are used to implement these ontologies in machine-readable form. Static ontology describes static aspects of the world, i.e. what things exist, and their attributes and relationships. Knowledge representation frameworks usually assume that the world is populated by entities, a set of attributes, and relationships to other entities. So the key concepts of static ontology are class, attribute, property, and so on [8]. Social ontology has been traditionally characterized in terms of actor, position, role, authority, commitment, and the like. For the purpose of this research, static ontology represents the static aspect of the quality management practices in the milk supply chain, e.g. organizations, products, quality requirement. Social ontology represents knowledge about the social structure of milk supply chain, e.g. soft quality requirement relationships. The knowledge of both static and social ontologies in this research is extracted from internal document files of one of the two biggest diary companies in china

A Static ontology

As noted above, the static ontology represents the static aspect of milk supply chain quality management including various kinds of entities, and there are complex relationships among them. In fig. 1, five key concepts are shown in the top level of the static ontology, which are milk supply chain organizations, quality criteria, milk product & materials, quality inspection tools, milk quality systems. The dashed with arrow shows the relationships between these five concepts, which are denoted by object properties. In particular, for milk supply chain organization, there are also relationships between its subclasses. The details of these relationships will be discussed at the class level. A detailed classification of these five concepts is given in the middle part of Figure 1. Take Milk supply chain organizations, for example. It has subclasses such as government, milk producers etc. Government together with downstream agents in the supply chain defines specific quality criteria for upstream ones. However, the entire ontology is so complex that what is known here is only part of it.

B Social ontology

The social ontology covers the social aspect of milk supply chain quality management practices, in particular; it represents the product and quality relationships among organizations in the milk supply chain by using a protocol in UML_RT, which is a UML-based architectural modeling language [9].

There are four principal constructs that are used for modeling structure in UML-RT: capsules, ports, protocols, and connectors. Capsules are complex physical, possibly distributed architectural objects that interact with their surroundings through ports. The port represents a distinct interaction point between the agent(one organization in the milk supply chain) and its environment (other organizations). To capture the complex semantics of these interactions, ports are associated with a protocol that defines the valid flow of information(signals) between connected two or more ports. Actors are active entities that carry out actions to achieve goals. a dependency describes an 'agreement' (called dependum) between two actors playing the roles of depender and dependee. With UML-RT, this can be depicted as in Fig. 2. In this study, the organizations are treated as actors and their relationships are described as dependencies between actors.

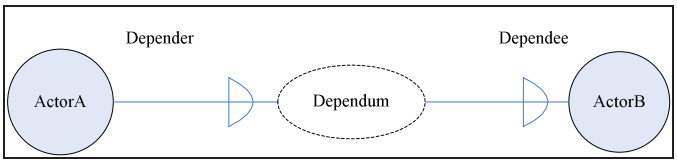

Figure 2. Mapping a dependency between actors in Tropos to UML-RT[9]

C Relationships between organizations

Product and Materials(P&M) relationship. The P&M relationships determine the role of each organization in the milk supply chain. Because the basic function of organizations is the exchange of product or materials, and then quality information flows between organizations. Product and materials refer to raw milk, auxiliary materials, kinds of semi-product and so on. Fig. 3 describes P&M relationships between organizations. The organizations are mapped to capsules and their P&M relationship is defined in the protocol P&M. Port here means the section or function of an organization which supports P&M exchange. The attributes of the protocol P&M and the protocol role defined give the details of this relationship. The Type attribute gives the type of P&M, e.g. Milk calcium. The Term attribute shows exchange time, e.g. 5 July 2009; and the Amount attribute gives the quantity of P&M. The upstream agent and downstream agent roles represent that P&M have been exchanged from Organization B to Organization A. The operation Validate of downstream uses kinds of approach to measure quality of P&M exchanged, such as ISO quality system evaluation and kinds of measuring tools.

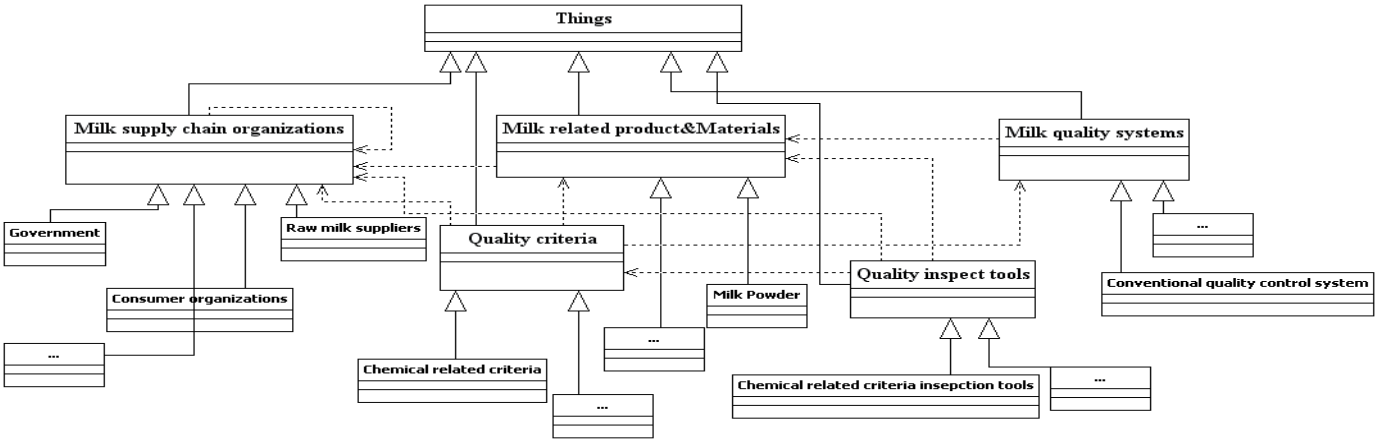

Figure 1. The static ontology for milk supply chain quality management practice

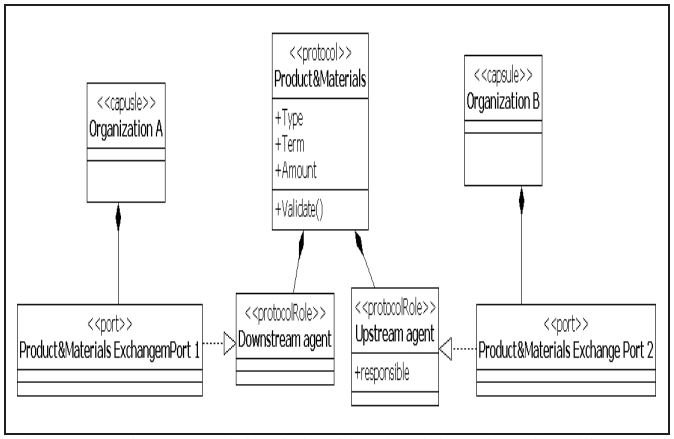

Figure 3. Product&Materials relationship of social ontology for milk supply chain quality management

Quantitative quality relationship. Government as well as consumer organizations and downstream organizations always have both quantitative and qualitative criteria for milk product and related materials. Quantitative criteria is number symbol, and can be evaluated directly by inspecting tools. It is contained in quality report from upstream agent. Qualitative criteria has no specific description such as "not adulterate", but can be inferred from other factors. Take "no ELISA Kit residual", for example, it can not be inspected. The organization that make quality requirement is defined as the quality demander, and the one that should make respond to quality requirement is defined as the quality responder. In the Protocol Quantitative quality requirements of Fig.4, there are attributes: Type, the type of certain quality requirement; Level, the rate level that type of quality determined by inspecting tools; Term, the time,and the corresponding inspection tools.

Qualitative quality relationship. For most of qualitative quality requirements, the corresponding information is not shown to quality demander timely. But qualitative quality information can be obtained by monitoring condition factors which may cause hazard quality problem, the content, audit process of these condition factors, etc. This relationship is shown in Fig.5. For ELISA Kit, the condition factors include water, feeding stuff for milch cow. The OWL description for class "the supply chain organization" is shown in Table 1. Relationship for P&M relationship is present in Table 2.

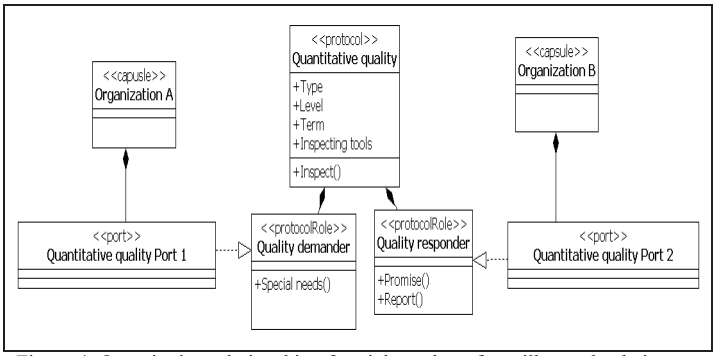

Figure 4. Quantitative relationship of social ontology for milk supply chain quality management

D Case Analysis

In this section, the case of Chinese milk scandal will be described using the model proposed in the paper. The hidden fact is that melamine was added into raw milk. No global picture for knowledge of quality management exists, so the milk industry is still not clear about responsibility each agent in the supply chain should take. From the Fig. 6, it can be clearly known what caused the scandal. Milk producer has both quantitative(e.g. protein level) and qualitative(e.g. not adulterate) quality requirement for milk shed, but milk shed only have quantitative requirements for raw milk suppliers. Thus milk producer did not get information from raw milk suppliers and milk shed for analyzing qualitative quality criteria timely. Obviously, adding melamine into the raw milk is a cheating behavior for increasing protein level, each cow produced much more raw milk than one five years before, so

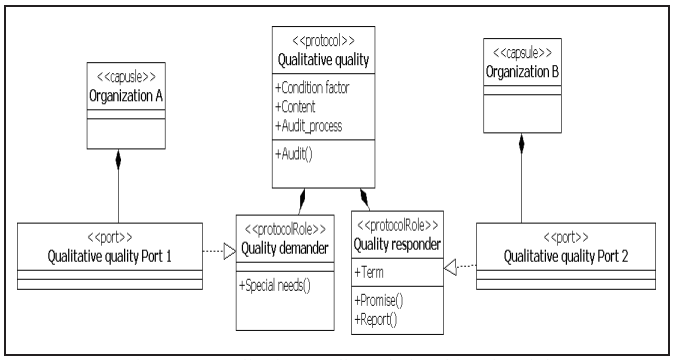

Figure 5. Qualitative quality relationship of social

TABLE I. OWL representation of class 'The milk supply chain organization'

```
<owl:Class rdf:ID="The milk supply chain organization">
<rdfs:subClassesOf rdf:resource="#Things"/>
<rdfs:subClassOf>
  <owl:Restriction>
    <owl:onProperty rdf:resource="provide
                product&materials"/>
…
```

TABLE II. Part of SWRL representation of P&M relationship of social ontology

```
…
<swrl: propertyPredicate rdf:resource="downstream agent">
  <swrl: argument1 rdf: resource="#y">
  <swrl: argument2 rdf: resource="#x1">
…
 <swrl: propertyPredicate rdf:resource="ypstream agent">
  <swrl: argument1 rdf: resource="#y">
  <swrl: argument2 rdf: resource="#x2">
…
<swrl:propertyPredicatee rdf:resource="P&M relationship">
  <swrl: argument1 rdf:resource ="#x1">
  <swrl: argument2 rdf:resource ="#x2">
…
```

it was infeasible for protein level to be high or even higher, "not adulterate" can be analyzed from the obove information[3]. In summary, there are several reasons why this scandal happened, first is that no monitoring of these qualitative quality timely; second quality information was not shared among organizations.

IV. CONCLUSIONS

Integrated supply chain quality management has attracted much more attention in recent years. It is a new approach to ensure food safety. Thus, entities of quality management practice in the milk supply chain together with relationships among them are represented in a conceptual model in this paper. The model is expected to propose an innovative perspective to quality management in a global dimension(i.e. the whole supply chain quality management) . With it, intelligent system can be designed to support quality information sharing between agents in the milk supply chain, and real time quality problem (e.g. causation of heavy metal residual) detection is feasible. This approach can be adopted in other industry.

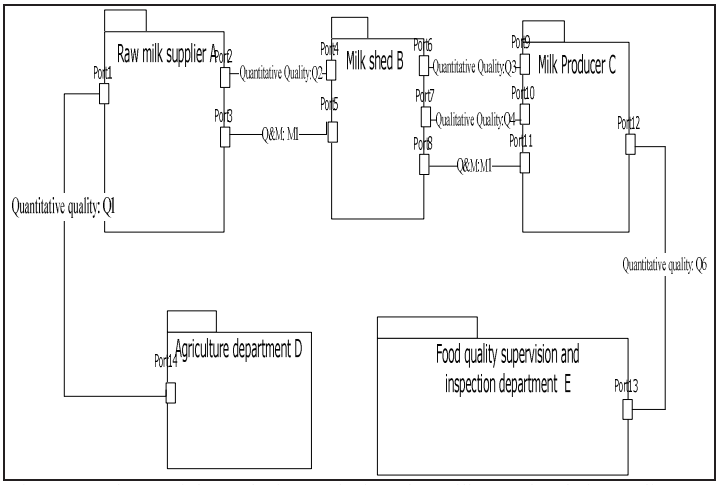

Figure 6. The partial graph for analyzing the milk supply chain quality management system in 2008

ACKNOWLEDGEMENT

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V. REFERENCES

[1] S. Thomas Foster Jr., "Towards an understanding of supply chain quality management," Journal of Operations Management, Volume 26, pp.461-467, 2008.

[2] J. Wang and D. Leung, " Determination of five macrolide antibiotic residues in raw milk using liquid chromatography-electrosprary ionization tandem mass spectrometry," Journal of Agriculture and Food Chemistry, Volume 54, pp.2873-2880, 2006.

[3] J. Yan and S.Wang, "A Belief-Desire-Intention for analyzing the cheating behaviour in quality control of diary product," IEEE International Conference on Digital Ecosystems and Technologies, 2009.

[4] H. Kaynak and J.L. Hartley, "A replication and extension of quality management into the supply chain," Journal of Operations Management, Volume 26, pp.468-489, 2008.

[5] I. Mahdavi and N. Cho, "A framework of e-based quality management for distributed manufacturing system," Contemporary Management Research, Volume. 3, pp.103-118,2007.

[7] I.Jurisica and J. Mylopoulos, "Ontologies for knowledge management: an information systems perspective," Knowledge and Information Systems, Volume 6, pp. 380-401, 2004.

[8] K. Ye and S. Wang, "Ontologies for crisis contagion management in financial institution," Journal of Information Science, unpublished.

[9] B. Selic and J.Rumbaugh, "Using UML for modeling complex real-time systems," Rational Whitepaper, Available at: www. Rational.com, 1998.